

Description of *Sarax buxtoni* (Gravely 1915) (Arachnida: Amblypygi: Charinidae) and a new case of parthenogenesis in Amblypygi from Singapore

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Abstract. The type material of *Sarax buxtoni* (Gravely 1915) cannot be located and has to be considered as lost. Therefore, a description compiled from a population in Singapore is provided, including morphological and taxonomical details presented for the first time. Comparisons with closely related species are supplied. Furthermore, we describe the occurrence of parthenogenesis in a population of *S. buxtoni*, representing the first case of asexual reproduction in a member of the genus *Sarax* Simon 1892.

Keywords: Whip spiders, asexual reproduction, Southeast Asia

Amblypygi, popularly called whip spiders, are characterized by their dorso-ventrally flattened body and strong, raptorial pedipalps armed with spines. The first pair of legs is extremely elongated and antenniform. These body appendages serve important multisensory functions and play important roles during mating, hunting, and antagonistic behavior (Weygoldt 2000). According to Prendini (2011), recent Amblypygi currently include five families, 17 genera and 161 species. Harvey (2013) mentioned 186 species and at the last count (Seiter & Hörweg 2013), the group expanded by two newly described species of the genus *Heterophrynus* Pocock 1894 (Giupponi & Kury 2013) and one species of the genus *Phrynus* Lamarck 1801 (Armas et al. 2013), elevating the number to 189 species. In Southeast Asia, the whip spider fauna includes four families (Charinidae, Charontidae, Phrynidae and Phrynichidae), with *Sarax* Simon 1892 (Charinidae) being the most diverse genus. Its 17 species are distributed in continental and insular Southeast Asia and Oceania with Papua New Guinea as the most eastern occurrence and India at the most western (Harvey 2003, 2013; Giupponi & Miranda 2012). Harvey (2003) further listed *Sarax mediterraneus* Delle Cave 1986 from Greece which is still included in Harvey (2013) and would, therefore, represent the most western distributed species of the genus *Sarax* Simon 1892. However, Weygoldt (2005) wrote about this doubtful record “[...] Therefore I suppose that somebody confused specimens and labels and erroneously replaced three *Charinus* specimens by three *Sarax* specimens [...]” (Weygoldt 2005: 12–13). Since then, nobody discovered the error and correctly identified these specific specimens, which are held in the SMF (Senckenberg-Museum, Frankfurt am Main, Germany). If *S. mediterraneus* is a valid species, the genus would contain 18 species.

Parthenogenesis in Amblypygi is reported from two species, both belonging to the family Charinidae: *Charinus acosta* (Quintero 1893) and *Charinus ioanniticus* (Kritscher 1959) (Armas 2000, 2005; Weygoldt 2005, 2007). *Charinus acosta* occurs in Cuba and is reported from different places through the country (Teruel 2011). *Charinus ioanniticus* is distributed around parts of the eastern border of the Mediterranean and represents the sole amblypygid occurring in Europe, if the reported occurrence of *S. mediterraneus* is truly due to a

misidentification. The European populations of *C. ioanniticus* are located on the Greek islands of Rhodes, living in subterranean passages of the ancient city of Rhodes, and Kos (Kritscher 1959; Weygoldt 2005). The population on Rhodes is an all-female population that reproduces parthenogenetically (Weygoldt 2007). *Charinus ioanniticus* has also been reported from Turkey (Kovařík & Vlasta 1996; Weygoldt 2005; Seyyar & Demir 2007), Israel (Rosin & Shulov 1960) and Egypt (El-Hennawy 2002), however all these reported populations reproduce sexually and males are present.

Sarax buxtoni (Gravely 1915) was first described under the name *Phrynichosarax buxtoni* with the type locality in Kubang Tiga cave, Perlis, Malaysia. Weygoldt (2000) considered *Phrynichosarax* to be a junior synonym of *Sarax* and transferred *P. buxtoni* to *Sarax*. Harvey (2003) transferred all of the remaining taxa from *Phrynichosarax* to *Sarax*. The diagnostic characters of the family Charinidae and the genus *Sarax* are discussed and revised in Rahmadi et al. (2010). In Singapore, two species of the genus *Sarax* occur: *S. buxtoni* and *Sarax singaporeae* Gravely 1911, the latter distributed in Malaysia and Singapore (the type locality is the Singapore Botanic Garden) (Harvey 2003). Weygoldt (2002) described the sperm transfer and the mating behavior of *S. buxtoni* collected in Singapore, but without clear description of the locality (“outskirts of Singapore” mentioned as the collection site). Furthermore, the author used the moderate description and poor figures of Gravely (1911, 1915) to identify the species. The type material of this study could not be found, and the former identification is unreliable because of the incomplete description of *S. buxtoni* by Gravely (1911, 1915). Considering the incorrectly identified material of Weygoldt’s study about the sexual reproduction of this species and our data about asexual reproduction in this species, here we provide (i) a detailed description of *Sarax buxtoni* from Singapore and (ii) a report of the first case of parthenogenesis in a *Sarax* species, which is the first known case of asexually reproducing amblypygids in Southeast Asia.

METHODS

Specimens of *Sarax buxtoni* were collected in Singapore, North West District, near Turf Club at 1° 19′ 29.47″N, 103° 47′ 25.97″E in a small park within the city. The specimens were found under an artificial stone cairn next to a small runlet.

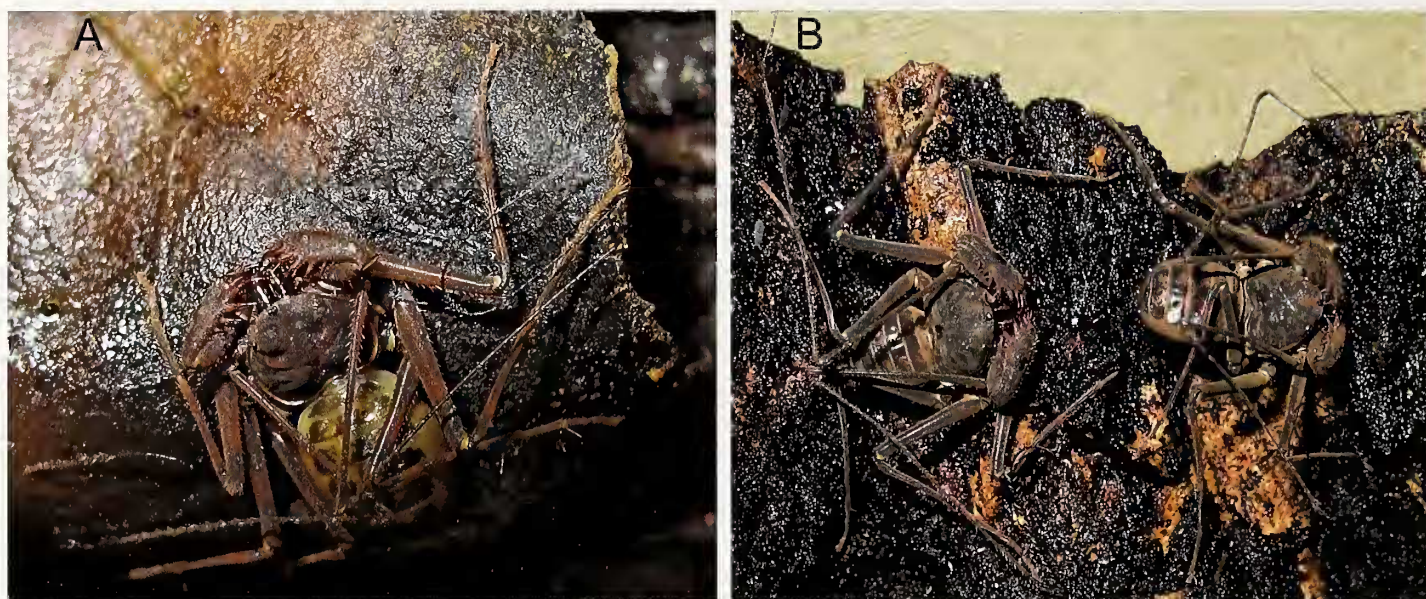


Figure 1.—Photographs of living adult *Sarax* individuals in standard plastic terraria. A: *S. buxtoni*, female. B: *S. singapora*, female right, male left (NHMW 21893). Note the sexual dimorphism in the length of the pedipalps.

This was the only stony place in an area of one square kilometer. Here, within half of a square meter, many female specimens were found living next to each other, sitting on the underside of stones in a very humid environment, protected from the sun and rain by the vegetation. *Sarax singapora* was found in similar microhabitats in Singapore, South West District, on the outskirts of Singapore, Jurong Bird Park at 1° 19' 7.34"N, 103° 42' 23.19"E. Nevertheless, this species was not found in high densities like *S. buxtoni* and was found to live mainly under stones and also in the leaf litter.

In the laboratory, we reared both species in plastic terraria of different sizes using standard methods. The enclosures contained a 2 cm deep layer of soil and pieces of bark in which the specimens could hide. Food consisted of cricket nymphs, *Acheta domestica* (Linnaeus 1758) and fruit flies, *Drosophila melanogaster* Meigen 1830. We kept all individuals under the same conditions (T = 26–27°C; RH = 65–75%) and fed them at the same intervals every seven days. Offspring were separated just after leaving the backs of the females and were raised under the same conditions as adults. All dead individuals were stored in 70% ethyl alcohol. Specimens were studied, measured and photographed under a stereomicroscope (Leica M205A) equipped with a Leica DFC420 camera, and digital images were processed using Adobe Photoshop 8.0.

The specimens were identified using the key and description of Gravely (1911, 1915) and compared with the voucher material from Weygoldt (2002). Nomenclature of the pedipalpal spines follows Quintero (1983a), modified according to Shultz (1990): pedipalps are divided into trochanter, femur, patella, tibia and tarsus (distitarsus+pretarsus or claw).

Abbreviations.—NHMW = Natural History Museum Vienna, SMF = Senckenberg Museum Frankfurt, SMNS = Staatliches Museum für Naturkunde Stuttgart, leg. = legit (collected), det. = determinavit (determined), syn = synonymized, ♂ = male / ♀ = female,

Material examined.—*Sarax buxtoni*: Holotype of *Sarax batuensis* Roewer 1962: **Malaysia**: 3 ♀, 6 juveniles, Selangor,

Batu caves (in different parts of the cave), 1959/60, leg. H.E. McClure (SMF 9913906 – RII/13906/51 – 68). **Republic of Singapore**: 4 ♀ adult (wild caught), 1 ♀ juvenile (wild caught), Singapore, North West District, near Turf Club, 1° 19' 29.47"N, 103° 47' 25.97"E, 14 September 2010, leg. and det. M. Seiter (NHMW 21891); 1 ♀ adult (captive bred), 3 ♀ juvenile (captive bred), same data (NHMW 21892).

Sarax singapora: **Republic of Singapore**: 1 ♂ adult (wild caught), Singapore, South West District, outskirts of Singapore, near Jurong Bird Park, 1° 19' 7.34"N, 103° 42' 23.19"E, 14 September 2010, leg. and det. M. Seiter (NHMW 21893); 2 ♀ adult, 1 ♂ adult (wild caught), same data except 2009, leg. S. Huber, det. M. Seiter (NHMW 21894); 3 ♀ adult, 2 ♂ adult, 2 juveniles (wild caught), same data except 27 June 1992, leg. S. Huber, det. M. Seiter (SMNS).

SYSTEMATICS

Family Charinidae Quintero 1986

Genus *Sarax* Simon 1892

Sarax buxtoni (Gravely 1915)

(Figs. 1A, 2–3)

Phrynichosarax buxtoni Gravely 1915: 439–440, Fig. 4; Mello-Leitão 1931: 52 (as *Phrynichosarax* [sic] *buxtoni*); Speijer 1937: 173; Weygoldt 1994: 244.

Sarax batuensis Roewer 1962: 519–520, Figs. 3a–b (syn. by Kraus 1970: 178).

Sarax buxtoni (Gravely): Harvey 2003: 8.

Diagnosis.—*Sarax buxtoni* can be distinguished from the closest geographical and morphological related species *Sarax singapora* by the following characters: (i) chelicera: dorsum with five fine lateral setae in *S. singapora* and none in *S. buxtoni* (Figs. 2I, L); (ii) moveable hand on the chelicera: in *S. singapora* with three highly cuspid teeth not equal in size, instead of equal size and rounded (Figs. 2I, L); (iii) sternum

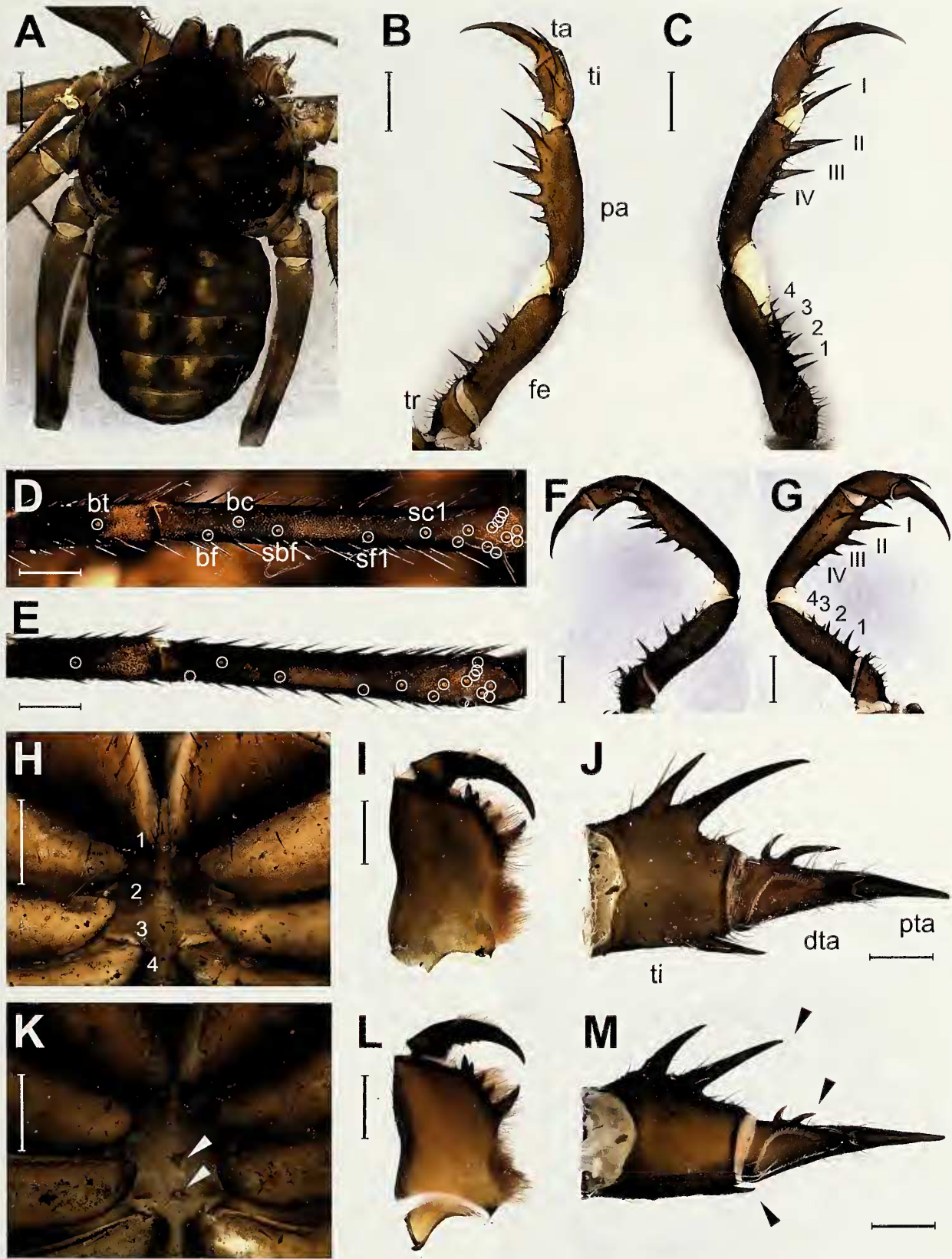


Figure 2.—A–D, H, I, J: *Sarax buxtoni*, female; E–G, K, L, M: *Sarax singaporeae* (F, G, L male; K, M female). A: habitus, dorsal. B, F: pedipalp, dorsal. C, G: pedipalp, ventral; dorsal spines of femur and patella numbered, tr: trochanter; fe: femur; pa: patella; ti: tibia; ta: tarsus. D, E: Basitibia and distitibia of walking leg IV, dorsal; trichobothria marked; basitibia (bt = basitibial), distitibia (bf: basofrontal; bc: basocaudal; sbf: subbasofrontal; scl1-x: series caudal and trichobothria, sf1-x: series frontal and trichobothria). H, K: prosoma, ventral; sternae numbered in H. I, L: chelicera. J, M: pedipalp, distal parts, proteropod. Arrowheads indicate diagnostic characters in *S. singaporeae*, ti: tibia; dta: distitarsus; pta: pretarsus (claw). Arrowheads indicate diagnostic characters; scale bar: A–C, F, G: 1 mm, D, E, H, I: 0.5 mm.

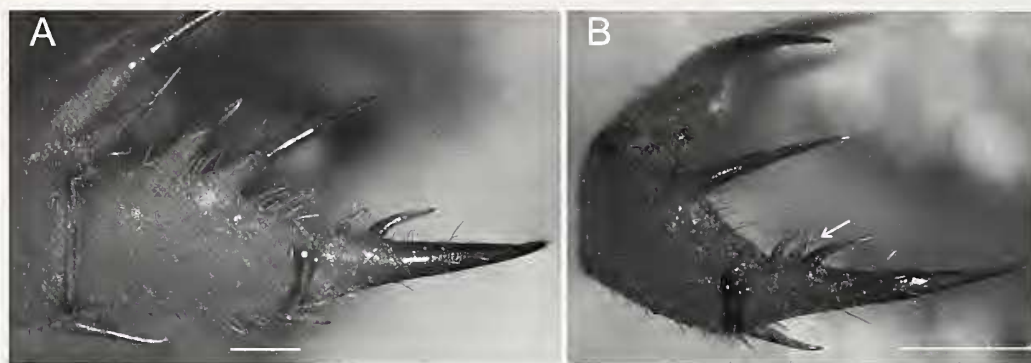


Figure 3.—Images of the distal pedipalp in *Sarax buxtoni*, adult female. Scale bars: 1 mm. A: An individual with normal spination on the right pedipalp tibia and distitarsus (SMF 9913906 – R11/13906/51 – 68). B: Another individual with an anomaly on the right pedipalp, indicated by arrow.

ventrally: with three visible sternites (second and third one rounded with apical paired setae) in *S. singapora*e instead of four (Figs. 2H, K); (iv) pedipalp tibia spination on the antero dorsal margin: proximal spine only 1/3 longer than distal one in *S. singapora*e, and without clear shared basin (Figs. 2J, M); and (v) pedipalp tarsus spination on the antero dorsal margin: about equal in size in *S. singapora*e instead of the proximal one more than half of the length of the distal one (Figs. 2J, M).

Description of adult female (from Singapore).—*Coloration (in alcohol)*: Chelicerae, pedipalps and carapace yellowish. Legs light colored (Fig. 2D); *in life*: Pedipalps and carapace light reddish. Opisthosoma light brown with light lines. Legs light brown to reddish.

Carapace (Figs. 1A, 2A): Carapace ratio width to length about 2:1.4; surface finely granulated without setiferous tubercles; median sulcus present with three sulci laterally on each half of the carapace reaching to the edge of the flange; flange wide and bend upward; anterior margin rounded, with six fine large frontal setae and several small ones. Median eyes without setae, tubercle black, arranged more or less in an oval form with prominent fovea; eyes facing antero-laterally.



Figure 4.—*Sarax singapora*e (SMNS): adult female, pedipalp distitarsus. Arrow indicates diagnostic character, illustrating the typical spination. Scale bar: 1 mm.

Lateral eyes close to the lateral margin of carapace, distance between lateral eyes about diameter of lateral eye, normal pigmentation. Frontal process triangular, visible from above.

Prosomal sternum (Fig. 2H): First sternite (tritosternum) elongated with paired apical, median and strong basal setae; second sternite less elongated but more than the following ones, with paired apical setae and one median seta; third sternite rounded and flattened with paired apical setae; fourth sternite (metasternum) visible with 1 seta in the middle.

Opisthosoma (Figs. 1A, 2A): Light brown, each tergite with a marginal yellow line, light-brown spots on either side of middle line.

Chelicera (Fig. 2I): Dorsum smooth with one fine frontal seta. Basal segment with four teeth. Lowermost tooth largest, and uppermost tooth is bicuspid, with upper cusp larger than lower one. Outer surface with small blunt tooth opposite bicuspid tooth; moveable hand with three teeth about equal in size.

Pedipalp: short and stout. Trochanter (Figs. 2B, C) with several small setiferous tubercles on antero-dorsal margin, one spine and nine setiferous tubercles ventrally; ventral anterior apophysis equipped with several prominent setiferous tubercles. Femur (Fig. 2B, C) with four major spines antero-dorsally (length $F3 > F1 > F2 > F4$), one minor spine between F2–F3, one minor spine between F3–F4, several setiferous tubercles and small tubercles; femur with four major antero-ventral spines (length $F1 > FII > FIII > FIV$), small tubercles present. Patella (Fig. 2B, C), antero-dorsal face with four major spines (length $P1 > P2 > P3 > P4$), with two minor spines, several setiferous tubercles and small tubercles; patella with three major spines (length $PI > PII > PIII > PIV$), several setiferous tubercles and small tubercles. Tarsus (Fig. 2J) with two major spines on antero-dorsal margin, length of proximal spine more than half length of distal one, one minor spine proximally, several setiferous tubercles and small tubercles; antero-dorsal margin with one major spine, several setiferous tubercles and small tubercles; distitarsus (dta) and claw (pta) divided, with two denticles on antero-dorsal margin, proximal denticle more than half length of distal one, distal one more curved towards the base as the proximal one; cleaning organ ventrally with around 30 modified hairs, several blunt setae on inner surface of tarsus, apotele present.

Legs: Tibiae II and III 4-segmented; basitibia IV 3-segmented; fourth segment with *bt* close to distal margin, *bc* in middle of *bf* and *sbf* (Fig. 2D), pulvilli present.

Table 1.—Reproductive events, dated, of consecutively numbered, wild-caught, female *Sarax buxtoni* and, in the cases of #2/1 and #2/2, captive-born female progeny of #2. Shaded entries indicate hatches of individuals from brood sacs produced after the parent had molted. Individuals #5–#9 produced brood sacs but it cannot be guaranteed that these individuals had not been previously inseminated. Most of the captive-hatched offspring died several days after molting, but two of them ultimately produced progeny without first being inseminated (#2/1 and #2/2). E = brood sac visible; M = molted; H = hatched; nD = no data available.

Female ID	Sequence of events →				
#1	E 09.12.2011	M 24.03.2011		E 02.06.2011	H 24.07.2011
#2	E 09.12.2011	H 22.01.2011			
#2/1	M 16.04.2011	M 16.07.2011		nD	H 03.01.2014
#2/2	M 22.04.2011	M 30.07.2011		nD	H 12.12.2013
#3	M 02.01.2011	E 03.04.2011		H 25.05.2011	
#4	E 29.10.2010				
#5	E 05.11.2010	H 06.01.2011		E 04.03.2011	
#6	E 13.11.2010				
#7	E 19.11.2010	H 12.01.2011			
#8	E 17.11.2010				
#9	E 09.12.2010				

Genitalia: Covered ventrally with genital operculum slightly concave apically, paired with two tubes projecting medially.

Measurements.—*Largest female (n=1):* Body length 7.29 mm. Carapace length: 2.78 mm, width: 4.07 mm. Median eyes to anterior margin of carapace 0.18 mm. Distance between lateral eyes 2.17 mm. Pedipalps: femur 2.49 mm, patella 2.58 mm, basitarsus 1.28 mm, distitarsus and pretarsus (claw) 1.71 mm.

Remarks.—The largest specimen of the nine specimens of *S. buxtoni* from Batu Cave (SMF 9913906 – RII/13906/51–68) has a notable anomaly. The pedipalp spination has been used extensively for systematic research and is an important character. Therefore the special spination of the right tarsus should be mentioned (Fig. 3B). Usually *S. buxtoni* has two spines on each distitarsus: large and conspicuous, the distal one about twice as long as the proximal one, the distal one is more curved near its base than is the proximal one (Fig. 3A). This especially large female bears three spines on the right pedipalp finger instead of two. The distal spines are about twice as long as the proximal one and the intermediary spine is one fifth smaller than the proximal one (length $\text{III} > \text{I} > \text{II}$). All three spines are equally curved. The rest of the spination is similar to the Singapore all-female population described here.

Parthenogenesis.—Nine adult females were used for this study. All of them produced at least one brood sac but only three of them can be guaranteed not to have been inseminated prior to brood sac production (Table 1). However, the possibility that only females were selectively caught is very low and can be disregarded. Three of the wild caught females molted and then produced a fertile brood. Of the hatching praenymphs (Table 1: #1, #2, #3), two individuals reached adulthood and reproduced independently, completely isolated from other individuals since birth. It should be mentioned, that several brood sacs were dropped and eaten by the females over time. Many of the praenymphs died during the first days, or did not eat *Drosophila* or small cricket nymphs.

DISCUSSION

The following discussion is subdivided into the three major parts of this paper.

Description.—Gravely (1911) reported the discovery of a new subspecies of *Sarax sarawakensis*: *S. s. singaporae*, from

Singapore. Later Gravely (1915) elevated this taxon to species rank under the generic name *Phrynichosarax singaporae*. In the same paper, based on two individuals (one adult female, one immature), Gravely (1915) described a new species, *Phrynichosarax buxtoni*, with the type locality in Kubang Tiga cave, Perlis, Malaysia. The original description is rather basic with a poor figure of the distitarsus spination intended to distinguish it from other species. For the description of *S. buxtoni*, we wanted to guarantee the validity and acceptance of the specimen used here. However, since the type specimen cannot be located, we decided to provide a detailed description. As the type locality is located in mainland Malaysia, we have limited our description to our specimen from Singapore. Here, we present for the first time a complete description of *S. buxtoni* with a demonstration of basic differences from the closely related *S. singaporae*.

Parthenogenesis.—Parthenogenesis is well known among arachnids, including: mites (Acari), harvestmen (Opiliones), true spiders (Araneae: Araneomorphae), pseudoscorpions (Pseudoscorpiones) and scorpions (Scorpiones). However, so far, parthenogenesis in whip spiders has only been reported in two species: *Charinus acosta* and *C. ioanniticus* (Armas 2000; Weygoldt 2007). It is reported that during molting whip spiders lose all stored spermatozoa (Weygoldt 1999). Yet to insure that sperm storage during molting events can be ruled out, we raised *S. buxtoni* specimens for two generations isolated from one another. Based on the observation of newly collected female specimens raised in captivity for two generations, we found that *S. buxtoni* is capable of parthenogenetic reproduction. The description of sexual reproduction in *S. singaporae* [misidentified by Weygoldt (2002) as *S. buxtoni*] from Singapore is now established. We argue that the specimens used by Weygoldt (2002) were wrongly identified based on our diagnosis above (Fig. 4). So the former described sexual behavior in this study belongs to *S. singaporae* and not *S. buxtoni*. Thus there is no male known from *S. buxtoni* populations because the type material cannot be found and is unavailable for study. However, our data do not allow us to determine whether this population is facultatively or obligately reproducing asexually. The type material consisted of two specimens: one adult female and one immature specimen not sexed. This sample size is rather low, though we cannot say if

the type locality is also a parthenogenetic population or not. Nevertheless, it could be possible that the population described here is facultatively reproducing asexually with a low prevalence or absence of males. Because of the location of the presumed all-female population in a small park, completely isolated by the city and concrete roads, a possible restriction to parthenogenetic reproduction could be comparable to the “insular parthenogenesis” described by Cuellar (1977, 1994).

Testing if females from this population can reproduce with males from other populations would verify if these females are obligately parthenogenetic or not. Conversely, it would be interesting to check if isolated females of other *S. buxtoni* populations, in which both sexes occur, are able to give birth without insemination to determine if facultative parthenogenesis is a common trait of *S. buxtoni*. Of interest is the fact that many of the praenymphs died during the first few days after emergence. We can argue that it is usually very tricky to raise and breed such small species over several generations, so this case is unlikely to be associated directly with possible deficiency caused by all-female brood resulted from non-fertilized eggs (as it is usual for thelytokous parthenogenesis).

Anomaly.—A similar case of asymmetrical spine transformation in the genus *Sarax* was yet unknown and, therefore, can be considered as very uncommon. Only a few asymmetries and anomalies are documented in recent literature, e.g. *Paraphrynus aztecus* (Pocock 1894) (as *P. azteca* [sic]) has bifid spines (Quintero 1983b). Here an adult male from Oaxaca, Mexico exhibited a transformation of spines III and V of the right pedipalp patella into bifid apophyses. In contrast the left pedipalp showed normal spination. Rowland (1973) reported an unidentified *Paraphrynus* Moreno 1940 species from Mexico with different length of spines on the pedipalp. Another case was documented by Baptista & Giupponi (2002) where asymmetry in the number of pseudo-articles of the basitibia in *Charinus troglobius* Baptista & Giupponi 2002 (four in general, but five in the right leg of two males) occurred. Armas & González (2001) showed different examples of anomalies in the pedipalps of *Phrynus eucharis* Armas & González 2001, *P. hispaniolae* Armas & González 2001 and *P. marginemaculatus* C.L. Koch 1840 from the Dominican Republic. The first author (MS) observed a *Paraphrynus* species, most likely *P. mexicanus* (Bilimek 1867) from Mexico, with bifid spines similar to the documented single *P. aztecus* specimen. Nevertheless, the anomaly observed in the *S. buxtoni* specimen is very uncommon and even deviates from the basic definition of the genus *Sarax*: pedipalp tibia with two spines, the distal one larger than the proximal one (Fig. 3B).

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